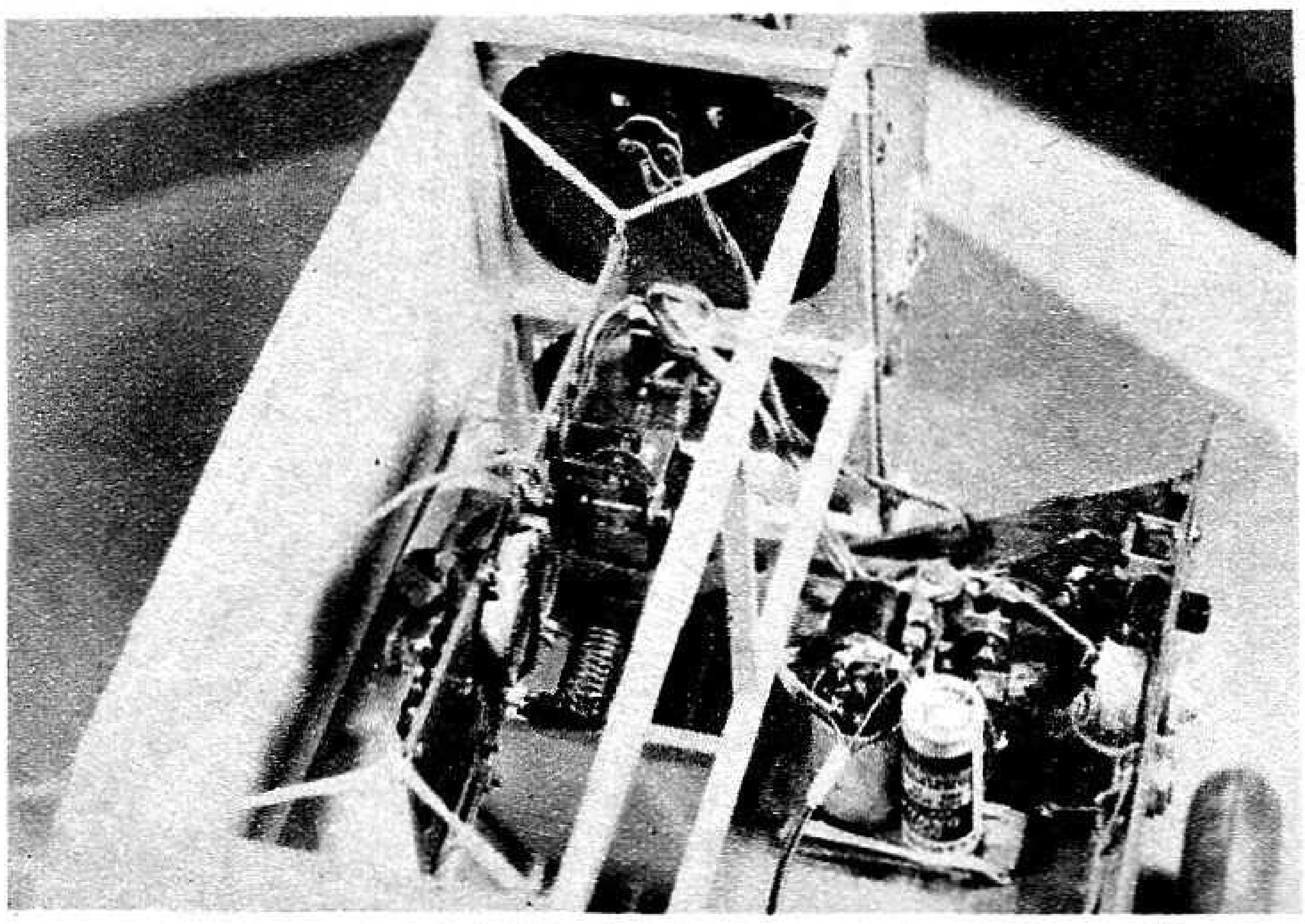
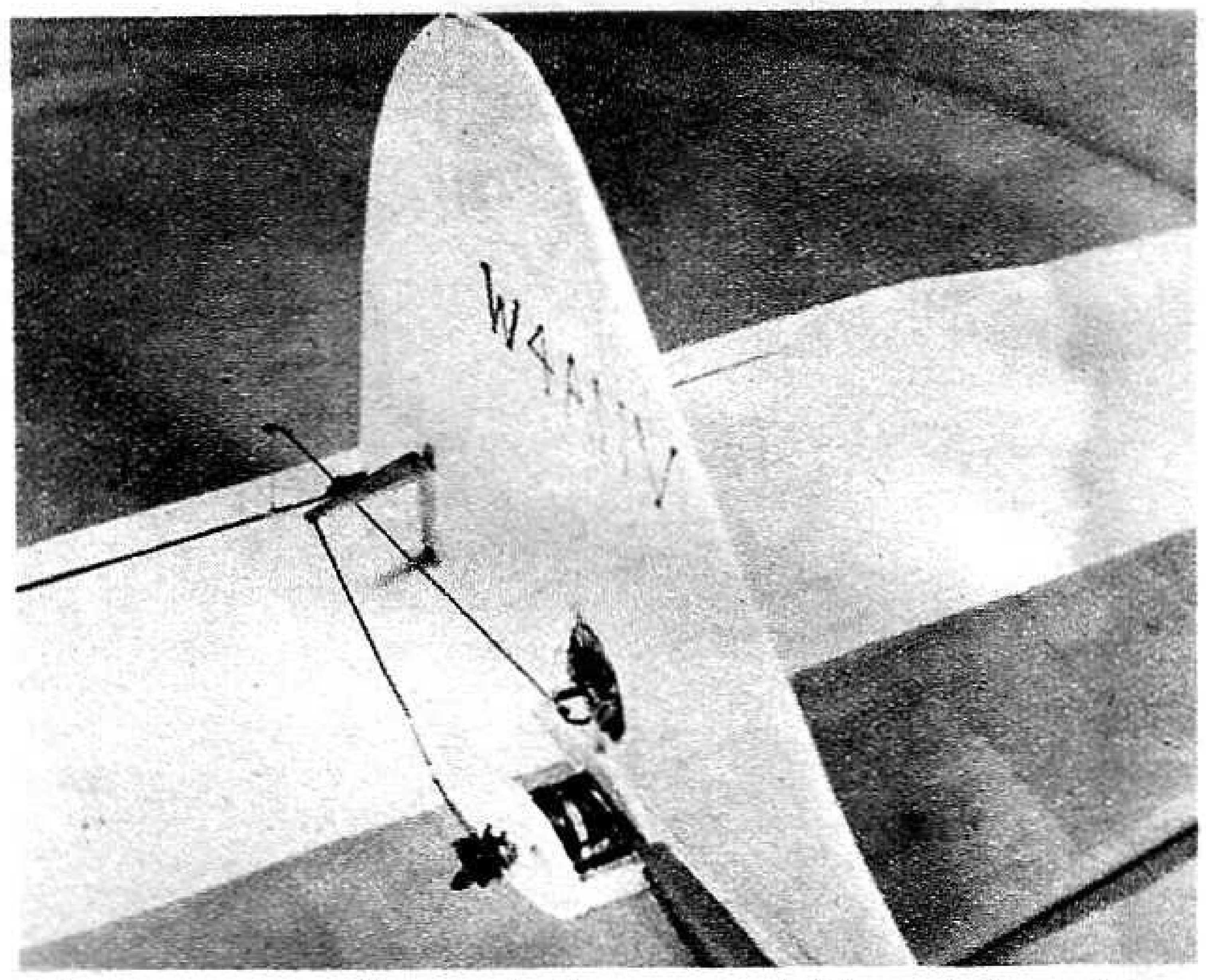
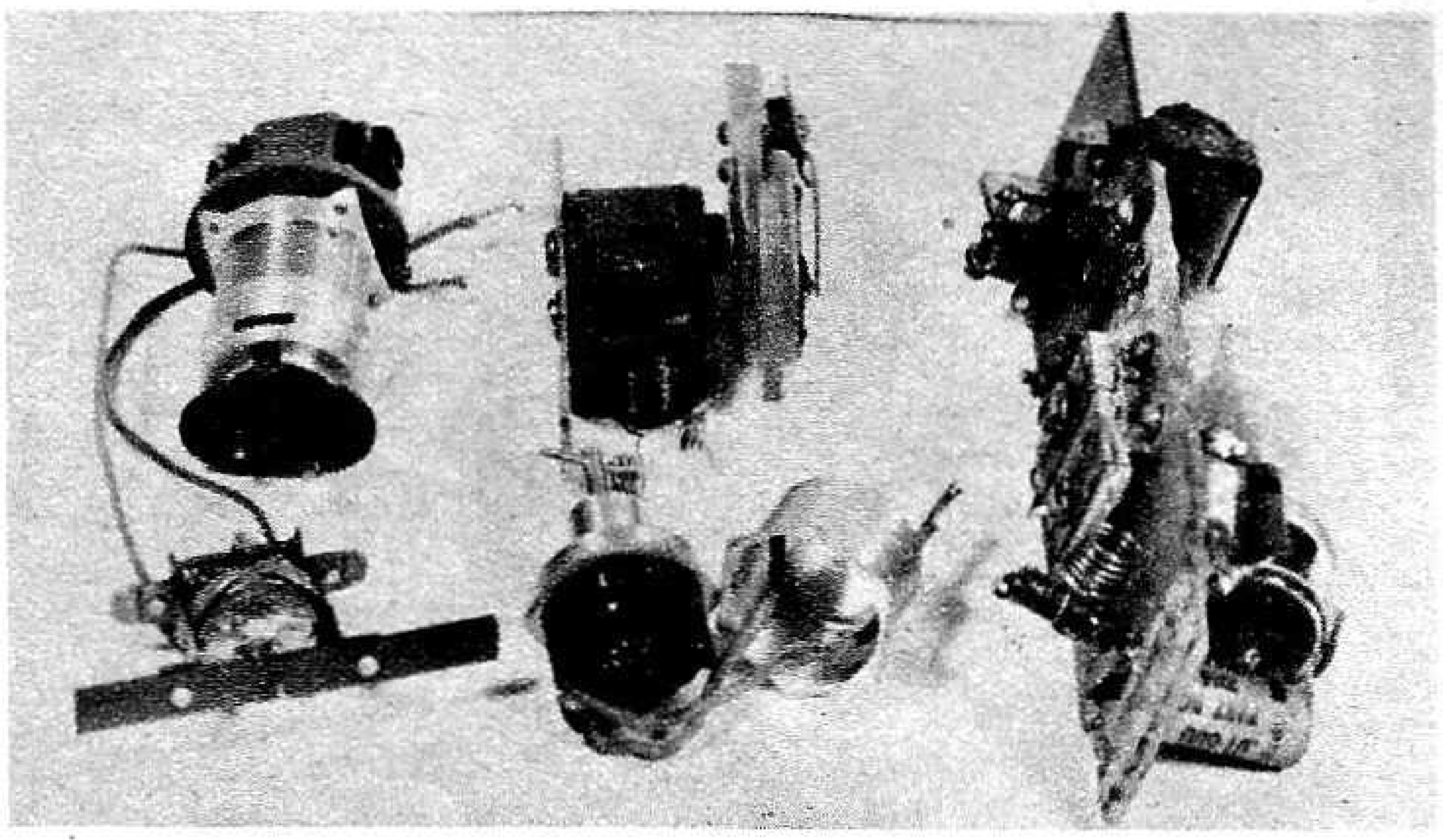


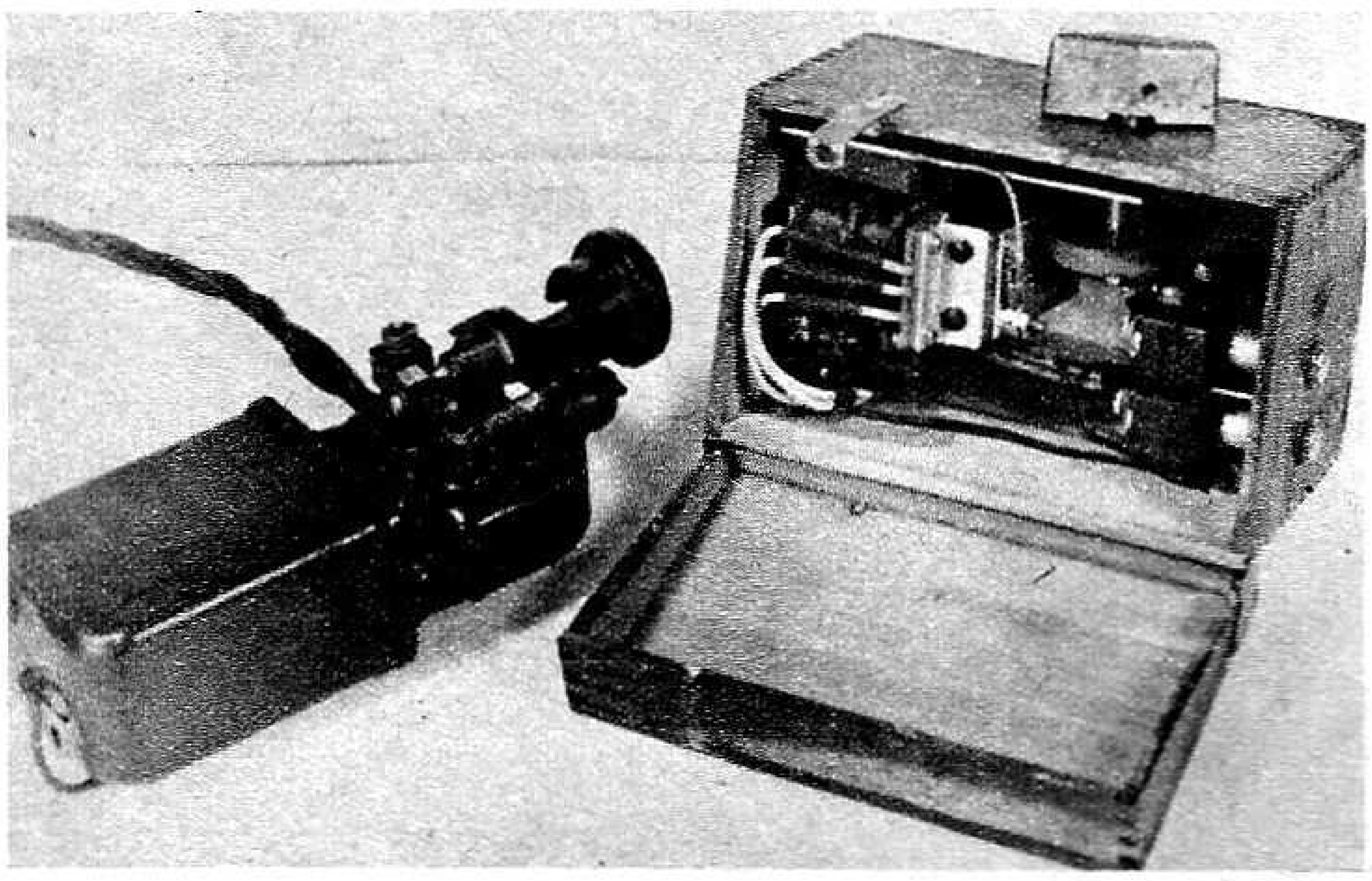
Radio equipment mounted in *Vagabond;* lower section pulls out like tray



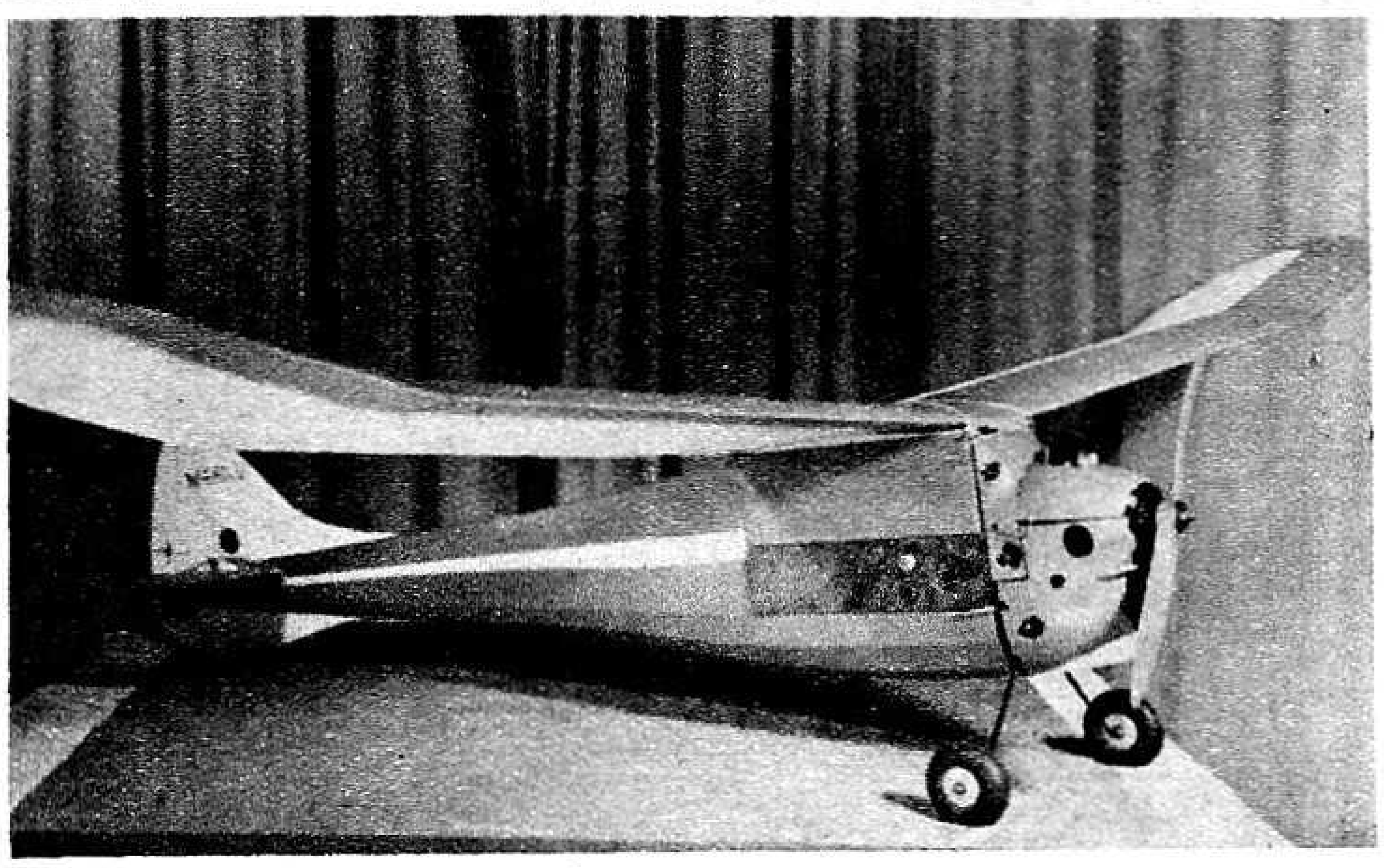
Actuators are small enough to mount right on tail surfaces



Actuators tried before present type was developed; right, prewar receiver



Single ground control at left; unit at right varies pulse length and rate



Modified radio controlled *Vagabond* all ready for action

PULSE RATE CONTROL

At last! A simple radio system that allows accurate "stick" control

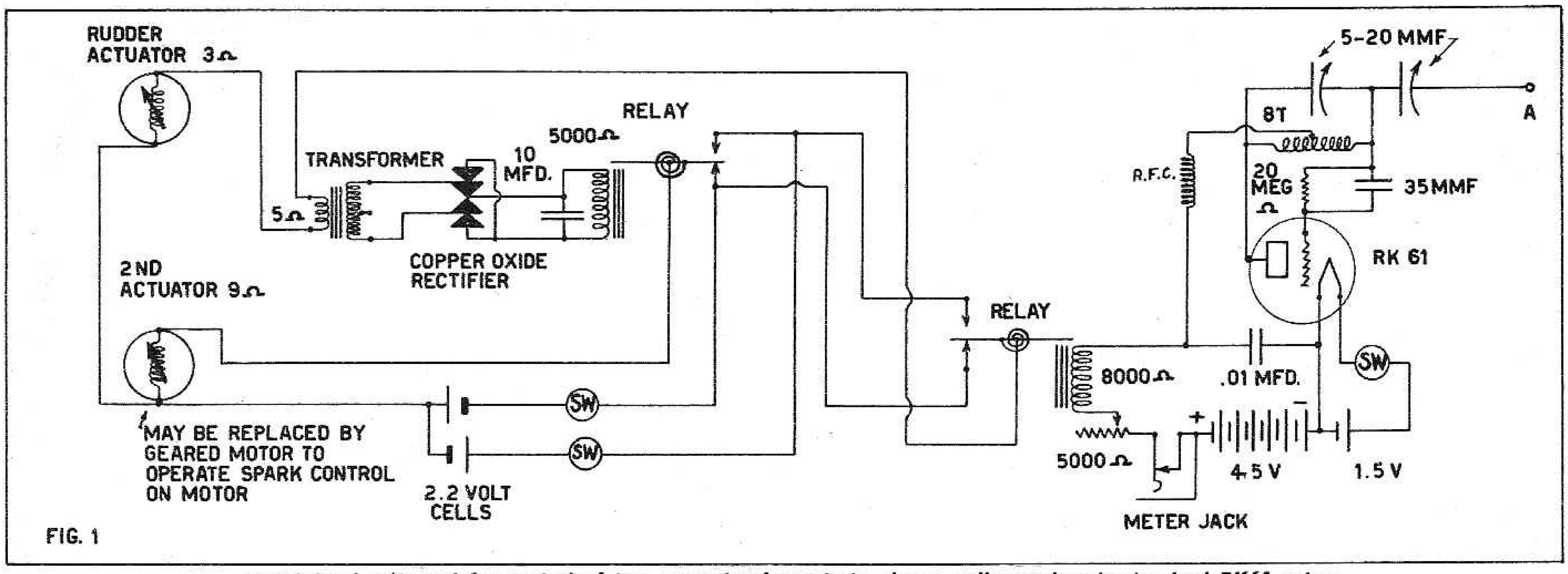
by GEORGE G. TRAMMELL

WHILE seeking a simple and accurate control system for model use many arrangements, both well known and otherwise, were tried out. Since the escapement method is the most widely used and the simplest, this was investigated first.

Did you ever try to fly an airplane by moving the controls suddenly rather than smoothly. I'll bet not many people have, because this is the first thing the instructor tells you *not* to do. I tried it to determine how accurately an escapement-controlled model could be flown—it was not so good. The lighter the wing loading the more sudden the change of direction would be; therefore the model would travel in a series of jumps.

The next thing tried was to fly as if by "Blip Control" (that is what the Army calls it). The controls are moved slowly, one at a time to the positions you think necessary for a particular maneuver. This is smooth enough, but it is impossible to control very accurately or quickly. This system is used in the Army RC target planes with audio channels to select the different controls. It requires a great deal of practice to become proficient in handling a plane with this method because only one control can be operated at a time using audio channel selectors.

The smallest Army RC plane I know of, which was landed by remote control in practice, was a regular two place *Culver* modified for the purpose. The landing gear was changed to a tricycle type and the nose wheel was connected to the rudder. An automatic pilot (AP) was installed which was operated by radio; the AP then controlled the plane. The throttle and brakes were operated from one control. After the throttle closes, if the control is held on the brakes are gradually applied. (This is a trick worth remembering for model purposes.) Eight audio channels are



Complete circuit used for control of two separate elements to plane; radio receiver is standard RK61 setup.

used and the filter and relay unit alone contains 9 double tubes and weighs 20 lbs. The receiver is a super-heterodyne, crystal stabilized.

The system of audio channel control doubtless has many virtues as it is used almost universally for target drones, and many RC model builders express hopes of using it. The lightest successful unit the writer has yet been able to make weighs over 1/2 lb. per channel. The possibilities are not of course limited to this much weight. Higher frequencies, such as 50,000 to 100,000 cycles, would enable us to employ air-core coils of relatively small size. It is quite possible that weight may be reduced to 4 oz. or slightly less per channel. Each relay and channel filter will require a tube, which uses up more battery. Hence it doesn't look too hopeful for lightweight models.

About this time a simplified scheme was worked out which I have found to fill the bill completely. Wouldn't you like to have a control system wherein the controlled surface on the plane followed exactly the position of the control in your hand, operating just the way the controls in the full sized plane do? When you pull the wheel (or stick) back 10% you get 10% up flipper. You can immediately advance or lessen the control at will. And, too, all controls may be operated simultaneously. Well, fellows, here it is—and it is even lighter than any other system we have seen.

For want of a better name the system described was termed "pulsed control." The pulses are varied in duration to operate one element, while another element may be two-position, or on-and-off, controlled by the frequency of the pulses. These two variations of the pulses have no effect whatever on each other (unless the pulse duration control were in its extreme position of all signal or no signal). Most everyone has heard of pulse transmission in connection with radar; it simply means short bursts of transmission followed by periods of no signal. In other words, the transmitter is rapidly turned on and off.

We can use any radio control transmitter and receiver we choose. The very simplest that will operate a relay in the plane is quite satisfactory. There have been many of these fully described in past issues so we will not go into detail on this.

Here is the way the pulsed control evolved from the more usual motor driven control. If signal-on gave us right rudder and signal-off gave us left, we could fly a nice zigzag pattern, controlling with a key or switch. So we put an electric motor in the plane, controlled by the relay of the radio receiver. Signal-on runs the motor one way turning the rudder toward the right; signal-off reverses the motor and we go left. If the signal is turned on and off rapidly, with the on and off periods the same, the motor should practically stand still; it will if the pulsing is rapid enough. With a fairly slow pulse rate—say 2 per second—the rudder will wiggle a little, but this is of no great consequence as it moves just as far to one side as to the other. The flight path of the model is not affected, and the rudder can now be made to remain in any position.

The ground control must have some automatic means of pulsing the signal. The writer used an old electric windshield wiper for the first model. The shaft that carried the wiper blade oscillates back and forth through nearly 180 degrees several times a second; this worked out fine.

The end of the shaft that protrudes was

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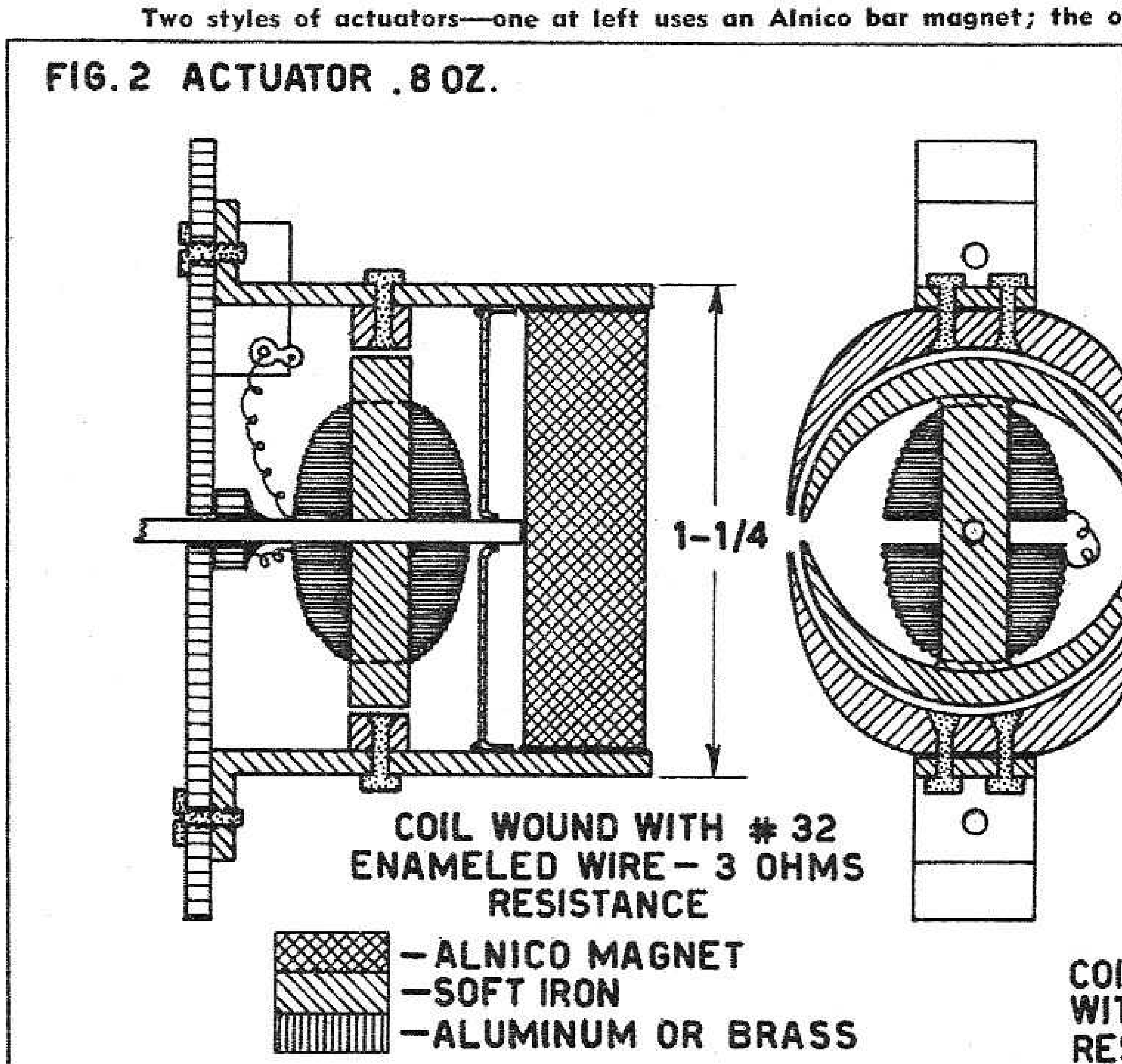
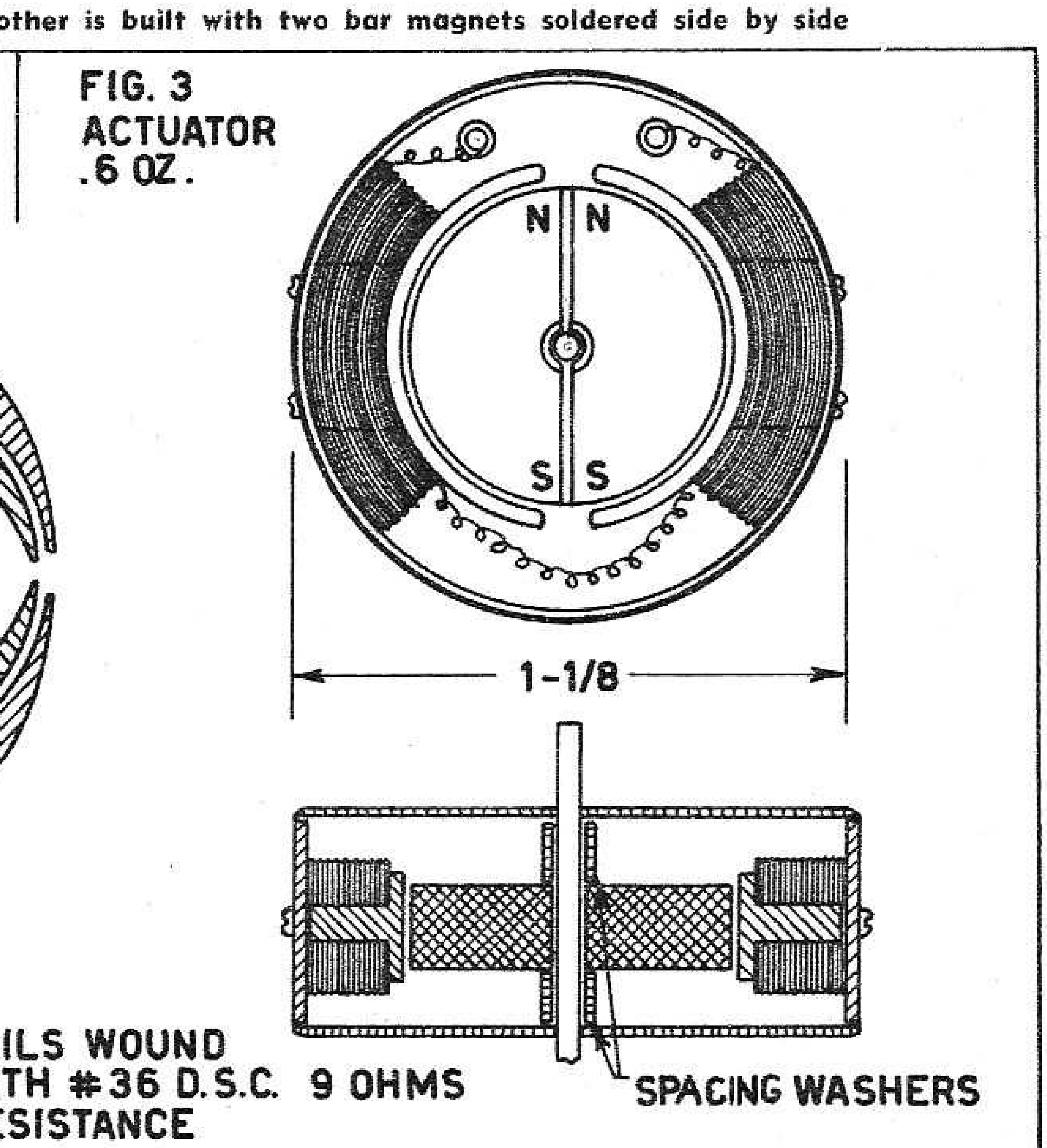
Two styles of actuators—one at left uses an Alnico bar magnet; the other is built with two bar magnets soldered side by side





Pulse Rate Control

(*Continued from page* 21)

ground to an oval shape to form a cam. Then a bakelite strip was hinged and held against this cam by a spring. A contact with flexible connection was affixed to the center of the strip on the same face that rides the cam. A coarse-thread screw with a contact on the end was held by a bracket so that it could be screwed against this contact. When the screw is backed off, the bakelite strip rides the cam and the contacts never touch. If the screw is turned in far enough it pushes the bakelite strip completely away from the cam, and the contacts make all the time. When the screw is half way the contacts make half the time and the cam holds them apart half the time; this is neutral. It required two turns of the knob to change from one extreme to the other. These contacts operate the keying relay in the transmitter through a convenient length of cord to the car where the transmitter is mounted.

When this arrangement was installed in the model a few trials showed a couple of defects. First, the rudder did not return to neutral when the control was centered. Next, even when you thought you had the control in neutral, the rudder would gradually creep to one side or the other due to irregularities of the contacts. It was decided that this defect should be corrected before making any flights.

In the meantime one of my buddies had built up a ship with escapement control and decided to adapt the equipment just described to his plane in place of his escapement. This experience proved quite interesting so let me tell you something of it. My fellow worker was William S. Howard of Atlanta, Ga. He, like so many others, decided to build a ship large enough to carry anything he could imagine, so it was a 12 footer with a big *Forster* motor. It had beautiful flight characteristics (so long as the CG was in its proper place); several flights were made with the escapement control, sometimes ending back on the field and sometimes two or three miles away in a tree. The model was quite slow although its weight seemed terrific compared to the usual size model; and once you got downwind it took up a lot of altitude to make any headway back against the wind. In addition to being slow flying upwind it is confusing to control a model when it is coming toward you since left-stick causes the model to go to your right, and vice versa. It is natural to make this mistake a few times at first or, when you get excited, even later.

With the wind against you and needing every foot of that altitude to get back to the field, excitement is at fever pitch. As you know, a model will change its course now and then with fixed rudder; therefore it requires constant vigilance to follow a fairly straight path. With short bursts of full rudder from an escapement to correct any tendency to stray from the straight and narrow path, any wrong rudder is disastrous, even if for just a moment. The plane makes a 180° turn, and if you allow it to continue to a full 360° to get headed back again the way you want it, you will probably find that it lost too much altitude in the turn to make the field. Another good flight gone wrong, and maybe the ship is finished for the day.

After several such experiences with the escapements, William and I worked most of one Saturday night changing over the control to use a geared motor instead. There had been 6 large flashlight cells mounted against the back of the engine firewall. These operated the escapement, and when we changed to the motor it was found that less voltage was required. Two cells ran it about right, so 4 were removed.

Sunday morning everything was ready. A good crowd was at our model flying site waiting to enjoy the regular Sunday display of busted free flighters when we arrived. After half an hour of testing, everything was all set. With escapement control William had always set the rudder to neutral, run the wing for the takeoff, and then run back to his control on the fender of the car. Today he decided someone should hold the control to correct for any tendency it had to creep while he ran the wing.

The takeoff was accomplished in a third the usual run and the plane nosed up immediately and went into a stall at 20 ft. The torque then took over and turned the plane left; naturally the fellow with the control gave her full right rudder, which did not take hold immediately due to the stalled condition. The nose gradually dropped off to the left and down she came in a screaming dive headed right back toward the takeoff point. All this time William stood frozen to the spot. Goggle-eyed and with mouth wide open he stared at the diving menace, all the while groping behind to take the control from the fellow who was holding it toward him fully 20 ft. away. As the ship gathered speed the full right rudder took effect, and at the bottom of the dive she suddenly changed direction, only 6 inches off the ground and about the same distance from William. As the plane zoomed up again the control exchanged hands and was given a quick twist to the left. The second zoom was much steeper and higher than the first.

She now had full left rudder helping the torque, so a complete wing over resulted and again down it screamed in a vertical dive, this time straight for the crowd. You never saw such excitement, repeated over and over again. Each dive seemed to pick a new intended victim, only to veer off to the right at the last possible moment and zoom up in a new direction and each time a little altitude was gained. After about ten such dives it was well above the field and folks began to enjoy the show. The final zoom was just beyond the trees on the horizon; then William turned to me and said: "Four batteries!" The extra power would enable more rapid operation of the rudder and possibly obviate such antics on the next flight.

During the next two weeks a new sort of an electric motor of the type still in use by the writer took shape. This motor does not run in the usual sense but makes something less than 180° of a turn with one polarity of battery, and turns back the same amount with reversed polarity. A short arm is soldered to the shaft to actuate the push-pull wire to the control horn on the rudder. Stops are provided on the end of the actuator (motor) shaft to prevent its making more than half a turn from one extreme to the other. The length of the control horn is adjusted for the desired rudder effect. Adjust so that the movement is small for the first flight; then gradually increase the rudder travel each flight until the desirable limit is found. Certain arrangements of LA and CG don't permit much rudder movement or the model will go into a spin (see some of Chas. Grant's articles on stability).

The actuator is really a two pole, permanent magnet field type electric motor without a commutator. For a more detailed description see drawings. The first one made weighed 8/10 of an ounce and had more power than was needed for the 5-1/4 lb. model; two medium sized cells were used, one for left and one for right, wired through the down and up contacts respectively of the radio relay. See diagram.

When building these actuators don't try to save too much weight by using very thin iron. This causes a serious loss of the number of degrees over which the actuator has a respectable amount of torque. A solenoid-type actuator would give the same operation to the controls, but they are notoriously inefficient. They require many times the amount of wattage from the batteries to accomplish the same work, besides weighing more themselves. Remember when building the actuator, magnetic force decreases inversely as square of the air gap.

The magnet used in the actuator at left of Fig. 2 is an alnico bar. For the smaller unit at the right of this illustration, two alnico magnets taken from the bases of the small plastic novelty dogs were utilized. These were soldered edgewise to the shaft, then were ground to the disc shape shown.

Ordinary soft iron does fairly well for the pole pieces and frames of these units. The main thing is to be sure the iron used will not retain magnetism.

Now I had something, how good wasn't realized just then. A 6' model of the Ryan

S.T. had been ready for some time so into it went the equipment. The first trial resulted in a ground loop on the take off, ending up in a low branch of a nearby pine tree. The ship had a lot of fancy work on it such as turn buckles in the wires, welded up aluminum and steel landing gear with shocks in the right places, aluminum cowling, silk covering, etc., and thus was very typical of RC experimenters' first ambitions. It looked mighty bad then.

An old faithful that had seen me through several contests, a "Comet *Sailplane*," was pressed into service now. A little aluminum rudder tab was added and the radio was set into the fairing behind the pylon on some sponge rubber mounts. The batteries were put into a box which slipped snugly into the balsa tunnel through the front part of the fuselage. The 11 oz. *Ohlsson 60* was removed and an old 6 oz. *Brown Jr.* was installed. Those sky-rocket climbs are not desirable in RC work. (A good class B motor is plenty hot for a four or five pound class C model.)

Of course it flew all right, but it couldn't be controlled on the takeoff. It was found that the bouncing of the model plus motor vibration was too much for the light contact pressure of the relay. More flexible rubber mounts on the radio and a shorter, lighter prop cured these troubles. Now it could be taken off, controlled by the radio.

It was found that a flight timer on the motor was necessary as the points seemed to be closed every time the motor stopped, necessitating changing ignition batteries each flight. The old type large horizontal gas tank gave about 4 minutes running, so the timer was set for three minutes. Flights averaged 7 minutes which is enough until you are sure of your range.

My transmitter was a three stage, master oscillator, frequency multiplier, and power amplifier affair with about 25 watts output. An AC power supply fed by an alternator (made from a refrigerator motor) was powered by a worn out one-lung gas engine (purchased for $5). The homemade governor on the latter went haywire one day and burned out a tube in the transmitter while I was making adjustments. Since a spare tube was not available, we shifted to my friend William's one tube transmitter used with vibrator supply, running off the car battery.

The model really outdid itself on that flight, climbing nearly out of sight before the timer cut the motor. She was put through the usual turns and figure eights on the way up—as the crowd always calls out some maneuver for you to execute—just to convince them we were really controlling it. A 360 turn to the left continued into a 720, and the control was set hard right with no result. This always means no signal; looking around at the antenna I saw a young fellow leaning against the mast, up which ran the open transmission line. Now on a multistage transmitter this would only have cut the power a little, but on a single tube self-excited job it detunes the transmitter's frequency to some extent which causes the receiver to lose the signal completely (a strong point in favor of the more stable performance of the slightly more expensive transmitter).

By the time the interference had been eliminated, the model was in a tight spin and held it right on down to the ground, nose first. It struck in a field of tall corn and, believe it or not, it was ready for another flight in 30 minutes after being returned to the flying field.

Thirty-three controlled flights were clocked up in a year with no more serious accidents. The model was repeatedly flown within inches of an obstruction with perfect confidence, and I could usually land it within reach.

The writer's goal is to build as small and light as possible, rather than produce big expensive heavy jobs that take so much time to build.

The entire equipment for rudder operation only was brought down to 8 oz. and installed in a class B pylon job with an A motor. It was impossible to find a place to mount things high enough in the fuselage to get LA and CG properly correlated, and the model would not stand much of a turn before nosing down. The climb was greater than expected or needed, although the model weighed over 3 lbs. This proved to me that a big motor is not a necessity for a limited amount of radio control. This model met a sad fate on the fourth flight when one end of the transmitter antenna came loose.

Next, a *"Vagabond"* class C (see photo) was selected and completed in three weeks. The old *Brown Jr.* was used again because it is so lightweight and easy to run. The rudder control was tried alone first, and results were such as you sometimes read about: the ship flew right off the drawing board. The weight, all up, was only 3-1/4 lbs. Using 2 pen light cells to operate the rudder actuator, which weighs 6/10 oz. itself, the installation was very light.

For years the idea has been running around in the writer's mind to operate a second control off the pulse rate. It is easily done using a couple of tubes, an input transformer, a few condensers and resistors, and the relay. But all this, plus heavier batteries for the additional tubes, adds weight too fast. There just had to be a better way—and there was.

A little energy is taken from the battery operating one of the actuators for a small enough period of time on each pulse not to affect it. Stored up in a condenser, the resultant accumulated voltage would be proportional to the applied voltage times the number of pulses per second. Then a relay coil connected across this condenser could be made to operate by varying the frequency of the pulses.

You know that only one spark comes from your ignition coil each time the points open, irrespective of how long or short a time they were closed before the break. This is the principle. It is only a matter of selecting the proper ratio transformer to produce a voltage that will match the relay operating voltage under the conditions at hand. The relay will not operate on an alternating current, and neither can AC be stored or accumulated in a condenser; thus a rectifier is necessary, but it does not have to be a tube. A copper oxide or selenium rectifier such as is used on some test meters serves the purpose. They sell for about two dollars and weigh a small fraction of an ounce.

Finally selected was an output transformer from an aircraft interphone amplifier (there are plenty of them in the junk shops). The output winding has a DC resistance of about 5 ohms, so this is connected in series with an actuator motor having 3 ohms resistance. This gives sufficient output to close the relay when it receives 6 or more pulses per second. With 4 or less pulses the relay will release.

This control was originally intended for throttle control where only two positions are required, but the writer just couldn't resist trying it on the elevators. The ground control box could be the same as used for the single control with a rheostat to change the speed of the motor.

A control was made as illustrated with three cams, one each with 1, 2 and 4 lobes, selected by the microswitches on the end of the box.

With two pulsed RF channels there can be 2 pulse frequency controls. With one of these used for the throttle, the other should be used as a safety. If the pulsing stops this relay could shut off all batteries, causing the motor to cut and the controls to neutralize. It could also release a catch on landing flaps causing the plane to settle faster. This should save some long chases after the model in case of control failure. Or the pulsing could be stopped momentarily to cut the motor and drop the flaps, then control of the pulsed channel resumed, if so connected.

Putting a rheostat of 5,000 or 10,000 ohms in the "B" battery lead of the receiver is strongly recommended because without this, voltage loss in the "B" batteries cannot be compensated for. While most radio receivers using the RK61 tube will work after a fashion when using the values given in any of the construction articles, it has been found through experience that each tube requires a slight variation in values

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of components to obtain the best sensitivity and steadiest operation. Also remember there is a 20% tolerance on the general run of condensers and resistors; therefore you don't always have the values marked. The most critical point in adjustment has been found to be the L/C ratio. That is the ratio of inductance in the tuning coil to the capacity across it.

One of the receivers in use before the war was set up for test, using a variable frequency signal generator. It was found that it worked ten times better at one frequency than at any other. This happened to be a frequency way above the 50-54 MC band. A new coil having more turns was substituted and then the best operating point noted, which was too low this time. The coil was clipped one turn and tried again. Each time a turn was clipped off the coil was stretched out longer to fit the supports until it was discovered that this was having quite an effect also. So starting with a new coil, each time a turn was clipped the test was repeated with several different spacings of the turns. Then the grid coupling condenser was changed and the same process repeated. Each new set of values was tried with various lengths of antenna and antenna series condenser settings. The final result was a thousand to one improvement in sensitivity and far less susceptibility to changes of the antenna (and to think it had been used successfully in its former state).

Now what about antennas? Well, a whole book can be written on this subject without fully covering all the phenomena, but here are a few high points pertinent to our conditions of operation.

I clearly remember how difficult it was to keep the people far enough away from the model not to affect the tuning. Also, when the model sat on the ground a different tuning adjustment was required than when it was up on a wooden table, and there is no telling how different it should have been when the operator himself moved away. So you see how important it is to arrive at such an adjustment that the antenna is not critically susceptible to outside influences. The greater sensitivity also means less power is required in the transmitter for any given range.

At present I am using a crystal controlled transmitter mounted in the trunk of the car. Each stage is fully shielded and the entire set is in an aluminum box. The input to the final stage is 10 watts. With no antenna attached and the trunk lid closed, the receiver will still operate the relay as much as 100 ft. away. This illustrates the fact that anything will work, up to a certain range. Conversely, without going into involved formula it will suffice to say that the power must be increased manyfold to double the distance. There is little to be gained by doubling the power in the transmitter, but with ten times as much power the difference in range is quite noticeable.

Much greater changes in range will be noted from changes in the transmitting antenna and from differences in transmitting and receiving antenna. With a horizontal antenna on the transmitter and the same on the receiver the greatest range seems possible. Most power is radiated broadside from an antenna, not off the ends, and the same is true for a receiving antenna. Therefore, with a wire running along the wing the shortest range is had when the end of the wing is pointed toward the transmitter. If a wire is run out both halves of the wing and the lead brought off the center, the range seems to be reduced considerably. If the plane antenna is made vertical the range is cut still more, but such an antenna does give a more even range horizontally. Remember that the wiring and batteries form the ground for the receiver and affect the antenna performance to a great extent as they actually become a part of the antenna system. If wires run to the tail of the ship they may become the main portion of the antenna, having as much effect as the other end. With a wire on the trailing edge for the antenna we have in effect an "L" shaped affair; this has very pronounced directional properties, being weakest between the open ends.

(*Turn to page* 83)

All this assumes that the model is in level flight. When in a tight turn the wing is nearly vertical, and when the tail of the ship is toward the transmitter the poorest reception exists. As my ship turns right when receiving a signal and left with no signal, it was easy to determine when enough signal to hold the relay was reaching the receiver.

Transmitting antennas have the above characteristics plus a few more because of ground effect. Within practical limits this general rule applies—the lower the antenna the greater the range near to the ground. but the poorer the range above. With the antenna more than half a wave length above the ground the range is very short on the ground and much greater above. Quarter wave vertical antennas have little range straight above them at any height from the ground.

To conclude this complicated subject, let me tell you what I am using after all these experiences as well as a lot of study. The transmitting antenna is a horizontal folded dipole mounted a little more than half a wavelength above the ground. The models use a wire along the trailing edge of one wing. The folded dipole is a circle of 3/8 in. copper tubing, 3-1/4 ft. in diameter. A 1 in. gap is cut out of the tubing on opposite sides of the circle. The coaxial transmission line connects to the open ends at one gap, and the other gap is left open. The greatest range is in the direction of the side to which the transmission line is attached. This makes a compact installation if not the most efficient one. The tubing is supported by three spokes, forming a wheel, the hub of which fastens to the top of the supporting member mounted on the bumper of the car. (Both wooden and metal poles were tried with no difference in results noted.)

For further information on this complex subject, I suggest that you read the chapters on antennas and HF transmitters in the A.R.R.L., or some other handbook.

The writer has several other new systems worked out that may prove to be even lighter where a multiplicity of controls is desired. None of these, however, have the accuracy of control and simplicity to be found in the pulse system described herein.

(EDITOR'S NOTE: We have found that the system of pulse control developed independently by Mr. Trammell is identical in operating principles with the control system patented by Jim Walker and used in Mr. Walker's 1946 Nationals winning radio control ship. While this "proportional control" system, as it is known to experimenters in the field, is used for the same purpose by both Mr. Trammell and Mr. Walker, control equipment carried in the model differs considerably. The actuator described in this article does not offer all the advantages of that worked out by Mr. Walker, but it is much simpler and lighter and can easily be built by the average modeler.)